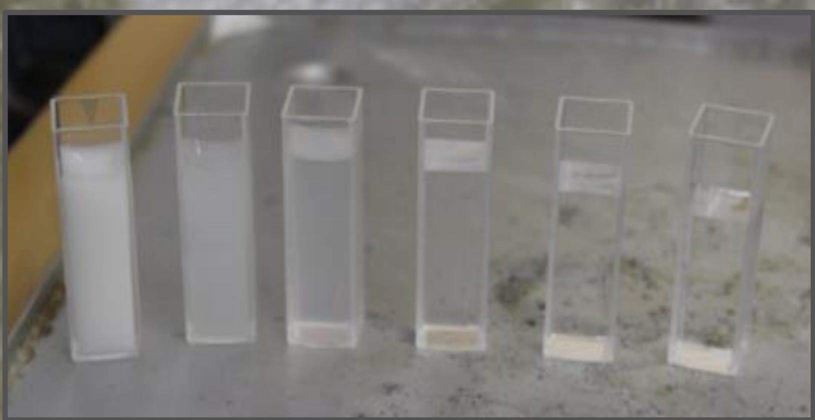
ENTRY TO THE STOCKHOLM JUNIOR WATER PRIZE 2017

Condensed milk clouds your vision:

Condensed milk calibration – a new method to determine turbidity of water samples at school

Marie Isabel Breuer
Amandus Abendroth Gymnasium
Cuxhaven
Germany



1 Preliminary matters

1.1 Abstract

During a student exchange project with India on the topic “water – basic resource of life on earth”, there was the task to analyse the water quality of different water samples from India and Germany. The turbidity of these samples was to be analysed as well. The usually used measuring standard is toxic and shouldn´t be used in school. This was the reason to establish a new measuring standard for turbidimetry by using condensed milk. Different condensed milk dilutions were measured with a photometer and a calibration graph was generated. Based on this calibration graph, the water samples were matched with the corresponding condensed milk dilution. In the following months, this method was improved and samples from the county of Cuxhaven were measured. Thus, a convenient turbidity measuring method was developed, providing reproducible results and being suitable for the usage in school when doing water analysis. Further development showed how this method can provide more information on the water quality and how the results will be applied to further monitoring of water samples from Germany and India.

1.2 Table of contents

1.3 List of abbreviations and acronyms

appr.	approximately
e.g.	for example
fig.	figure
i. e.	which is
ln	natural logarithm
NTU	Nephelometric Turbidity Unit

1.4 Acknowledgements

My scientific work was supported by the following persons: my teacher of Mathematics, converting the functions and explaining me the application of the natural logarithm; my teacher of English, checking my English translation for grammatical and spelling mistakes; my supervisors instructing me into the excel program and into the statistical analysis of scientific data, into the usage of a photometer, and they explained all the lab handling procedures.

I would like to thank everybody who supported me and my studies over the past twelve months. Special thanks refer to *Jugend forscht* for their financial support of my participation at the Junior Water Prize 2017, my teachers and supervisors *Dierk Müller* and *Dr. Katja Steinmetz*, who let me learn a huge amount on new aspects of natural sciences and made me overcome my own limits, *my parents* and my good friend *Lennard Hellweg* for encouraging and for being there in any stressful situation.

2 Introduction

2.1 Indian-German exchange project leading to the presented study on turbidity

"Water – basic resource of life on earth." Under this headline my school carried out a student exchange project between Cuxhaven and Kolkata (India). We analyzed the physical-chemical properties of the water molecule allowing the existence of life and compared the drinking water abstraction processes and the sewage clearing processes of both cities. One objective was to compare water samples taken from e.g. the river Ganges and the river Elbe by determining ammonia, nitrate, phosphate, heavy metals and other parameters.

Figure 2.1a: turbid water of the river Ganges, which gets conditioned to fresh water in a purification plant in Kolkata

Figure 2.1b: Samples from the purification plant, left one: almost clear, purified; right one: turbid, not ready purified (own pictures)

During the visit of a water purification plant in Kolkata, where water from the river Ganges is converted into drinking water, I asked myself how this process can work as the Ganges´ water seemed to be grey-brown, turbid and not drinkable at all (fig. 2.1a, b). This question made me take a closer look at the turbidity of these water samples.

Our school does not have an adequate turbidimeter, only a simple photometer which led to the problem of inventing a new determination method.

2.2 Turbidity

Turbidity is an optical impression which describes the property of transparent media to absorb and disperse light rays (fig. 2.2). The turbidity is caused by undissolved solid matter located in the fluid media [1, 9]. This solid matter is described as particles having a different refraction index than water [8].

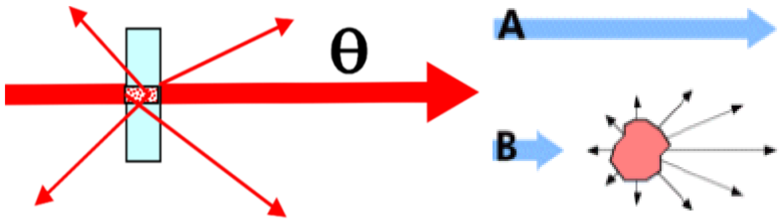


Figure 2.2 [1, 9]: schemes showing what happens if a light ray passes through a sample containing small particles. Some light rays get scattered (thin arrows) and some get through the sample (transmission) (thick arrow).

Thus, these particles may be not only solid materials, like clay and mud particles, but also colloids such as undiluted oil in water, milk and also gas bubbles.

Turbidity is not a clearly defined parameter – it is a subjective impression and because of this, turbidity measuring instruments are calibrated by a reference material.

Years ago, the turbidity measuring was quite similar to the optical test of oculists. The sample was filled into a glass and held in front of a table with numbers (fig. 2.3). The last visible number represents the level of turbidity [3].

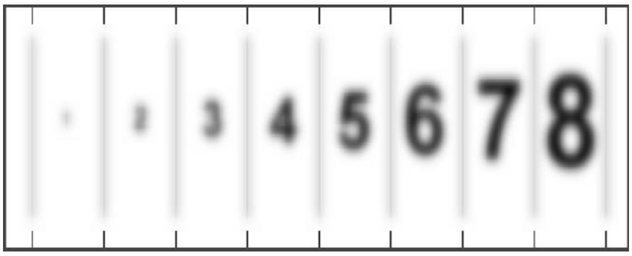


Figure 2.3 [3]: Optical test used in former turbidimetry. The sample was hold in front of the numbers 1 to 8 and the last identifiable number represented the grade of turbidity.

This method is very subjective and makes it impossible to compare a variety of samples analysed by different observers. This is the reason why todays scientists use a turbidity measuring device they can insert the water sample within a cuvette. A light ray of a certain wavelength can be chosen and sent through the sample. With this measuring device you can determine the absorption, the transmission and the dispersion of the water sample. Absorption is the fraction of light being absorbed by the sample, which gets lost within the sample itself. The transmission describes the remaining light that is not lost after passing the sample. During a dispersion measurement the light which is diverted in a 90° angle is recorded (fig. 2.4 [5]).

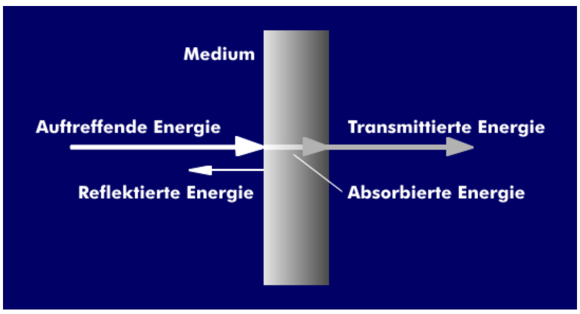


Figure 2.4 [5]: Consequences energy subjected into a medium. A part of it gets reflected or scattered. Some other part gets absorbed and the third part gets transmitted. This part is the remaining energy which is not changed inside the medium.

Generally, turbidity is not proportional to the size and form of the particles in the medium [9]. This makes inventing a measuring method to receive comparable values difficult. The use of a dispersion measurement is preferred for measuring in a low concentration level, the transmission measurement for measuring in a high concentration level of undiluted particles. The reason for this is the multiple dispersion in a sample with a high concentration because the light rays are reflected by the high density of the particles. The light cannot continue evenly, thus, the dispersion is not proportional to the concentration any longer [11]. Anyway, by measuring the transmission you only receive relative numbers without any unit complicating the comparison of results obtained from different methods or sets of samples. This is the reason why it is necessary to set up a calibration graph e.g. with formazine. A calibration graph shows the transmission of a standard in dependence to the dilution and allows the mathematical analysis of the parameter – i. e. the turbidity of different samples. Laws instruct to use formazine as standard for drinking water analysis with the unit NTU [2, 9]. Dispersion is measured in a 90° angle at 860 to 880 nm (ISO standard). However, formazine is not suitable for the usage at school because it is toxic and therefore prohibited. This is the reason why another substance had to be found as a suitable standard [4] displaying a clear mathematical correlation between the used concentration and the measured transmission. Additionally, this method had to be carried out when using a common and simple photometer allowing only the determination of the transmission.

2.3 The calibration standard - condensed milk

During breakfast, a glass of milk and a glass of water on the table were attracting my attention. You cannot see through the glass of milk because the milk is white and intransparent but if you dilute it with water, it will become more transparent and you can look through it better. The white colour of the milk is due to the fact (fig. 2.5 [6]) of having little lipid droplets in water known as micelles [7]. The micelles formed within the milk belong to the type of liquid colloids in a liquid medium – the emulsion. That means milk represents turbid water. Actually, these lipid droplets have a similar size to formazine [8]. This had to be the solution: You could dilute the milk in a range to relate the measured transmission values with the corresponding dilutions. Thus, the milk could act as a calibration standard for the turbidity measurement.

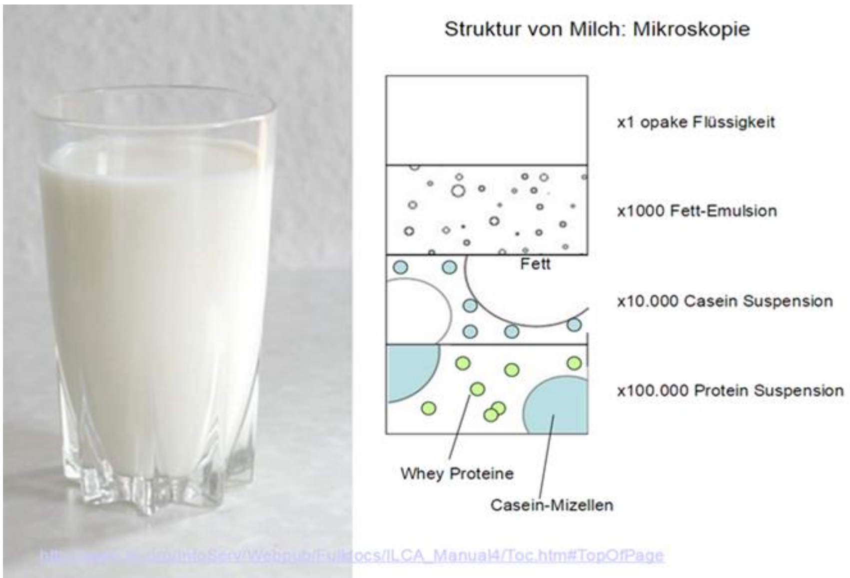


Figure 2.5 [6, 12]: structure of milk, an emulsion of small blobs of fat (i.e. micelles).

The idea was to prefer condensed milk to “normal” drinking milk because of the longer storage life and a higher fat level because water had been removed during the production.

However, as turbidity is caused by colloids within the water samples, they mainly represent clay minerals within the range of 1 to 1,000 nm and belong to the group of dispersion colloids [12]. Thus, they refer to the group of a “sol”. The question arose, whether a milk calibration (containing micelles, i. e. association colloids) could lead to reasonable turbidity values of environmental water samples.

2.4 Aims of the study

Altogether, the following questions were addressed:

- Is condensed milk a suitable substance as a calibration standard for turbidimetry?
- Is there a mathematical correlation between the milk concentration and the measured transmission? And if so, what kind of mathematical correlation?
- In which span of dilution has the calibration graph to be established to cover the whole transmission range from 0 to 100 %?
- How many dilutions are required to get a reliable calibration graph?
- Is it possible to store the condensed milk stock solution to prepare a series of dilution ranges? And if so, which conditions are necessary?
- Do bigger suspended sediment loads in water samples like those in the samples of the river Ganges break up the measurements?
- Do variations in term of colour like those in the samples of the river Ganges break up the measurements?
- Is it possible to use the condensed milk standard to determine reasonable and comparable values of the turbidity of water samples?
- Does condensed milk related turbidity give any idea of the water quality?

3 Material & Methods

3.1 Determination of a condensed milk calibration graph for turbidimetry

Condensed milk of the brand “ja!” was used to set up a stock solution by establishing a dilution of 1:100 (= 0.01). This 1:100 dilution was chosen because results with a 1:10 dilution used in the initial experiments during the Indian project showed that they were not within the confidential transmission range. The measured values of the 1:100 dilution were found to be always between 3.3% and 0.8% transmission. By storing the condensed milk stock solution in the refrigerator it is possible to use it up to seven weeks, until it coagulates. Storing the stock solution in the freezer causes coagulation directly after thawing it. Thus, this way of storage was not convenient (not shown). This might be caused by the formation of colloids with different sizes and structures after melting as ice crystals destroy the initial colloids.

A dilution range was set up when diluting the stock solution further to receive different transmission values to fill the whole 0 – 100 % transmission range. To get a good comparison of the values, the dilutions 1:1,000 (=0.001); 1:10,000 (=0.0001) and 1:100,000 (=0.00001) were measured on every day of the experiment as control.

Because of the photometer type (Perkin-Elmer spectrophotometer PE 35; Waltham, Massachusetts, USA), the infrared wavelength (860 or 880 nm literature value [8, 9]) of the light rays couldn´t be reached but the wavelength of 825 nm was applied being the maximum wavelength of the used photometer and still within the infrared range. With this photometer the transmission, the percentage of light passing through the sample, was recorded. Macro cuvettes made from plastic were used (fig. 3.1).

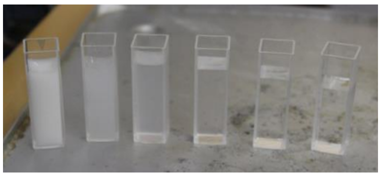


Figure 3.1: dilution range of condensed milk, dilutions of 0.1; 0.01; 0.001; 0.0001; 0.00001 and 0.000001 in synthetic cuvettes used for the photometry.

All measured values were transferred into in a Microsoft Excel table (Version 14.0 for Windows 2010). A plot was made with all data and a regression analysis yielded a calibration graph with the corresponding function describing all measured values (fig. 4.5).

Conversion of the function from the Excel-diagram:

$$y = 100.01e^{-374.8x}$$

x = Dilution of the condensed milk; y = Transmission (%)

$$x = \frac{\ln(\frac{y}{100.01})}{-374.8}$$

Consequently, this function allows to assign a condensed milk related turbidity value (x) to any water sample by calculating the natural logarithm ln of the quotient of the transmission value (y) and 100.01 and subsequent division by -374.8 .

3.2 Application of condensed milk related turbidity to the turbidity of water samples

Water samples for the turbidity measurement were taken at different sites: From a private duck-pond, from the marina of Cuxhaven, from an agricultural ditch in Dorum and from a tide-pool in the Wadden Sea of the river Weser in Dorum-Neufeld. Additionally, clear and naturally turbid apple juice of the brand “WIESGART” from “Aldi Nord” was used. All samples have been measured in a 1:1 dilution at a wavelength of 825 nm. In case of a low transmission value the samples have been diluted into a 1:2 or 1:4 relation.

Samples with a high content of particulate matter have to be shaken before measuring and the transmission value has to be taken fast to avoid mistakes due to sedimentation.

The measured transmission values of the samples could then be applied to the function of the calibration graph (fig. 4.5) and the corresponding condensed milk related turbidity could be calculated. As one to four measurements of every sample were taken, the average and the standard deviation were determined, too (by the corresponding function of Excel).

Samples with a low turbidity show a high transmission and a high condensed milk dilution. Samples with a high turbidity have a low transmission and a low condensed milk dilution.

3.3 Application of the developed method on water samples taken during the student exchange project with India

Water samples were taken in May 2016 from the river Ganges, the Kolkata wetlands and from the Indian tap water in the Sushila High School in Kolkata (former Calcutta) and transferred to Cuxhaven, Germany. In Germany the samples were taken from an agricultural ditch, the marina of Cuxhaven, the river Elbe and from a tide pool.

Turbidity was determined as described above. Anorganic ions, e.g. nitrate or phosphate were determined by using an Aqua Sera test box. Heavy metal contents of copper, lead, arsenic and also iron were determined by the lab *Iben* in Bremerhaven (Germany). Correlations of parameters were tested using the Excel program.

3.4 Microscoping the structure of condensed milk and of colloids of the water samples

The undiluted condensed milk and the water samples were transferred to a microscopic slide and were observed with a 600x magnification and photographed with a mobile phone camera (Motorola Moto G3) through the ocular each with the same enlargement.

Figure 3.2: Microscopic pictures of the condensed milk (left) and the marina water sample (right) at 600x magnification.

4 Results & Discussion

The aim of this study was to find out whether condensed milk represents a suitable standard for the turbidity measurement of different environmental water samples taken in Germany and

India. During the already mentioned initial experiments upon an Indian student exchange promissing results had been obtained. These led to the continuance of the project.

4.1 Determination of the mathematical correlation between the dilution of the condensed milk and the transmission

The measurement of the transmission values was carried out within some weeks after setting up a stock solution with a dilution of 0.001. That stock solution was diluted into different further dilutions. The stock solution could be stored up to seven weeks in the refrigerator without moldering but the reliability of the graph sank during this time onto an $R^2 = 0.9814$ (not shown) in comparison to an $R^2 > 0.99$ (not shown) of the fresh solution, which shows a lowering reliability overtime. The closer the R^2 approaches 1.0, the higher is the reliability of the graph, i.e. the better the measuring values are described by the function. Due to this fact a new stock solution with the same dilution had to be set up during the developmental phase of the measuring method. Due to several repeats of the transmission measuring, several calibration graphs were determined in a concentration range from 0.01 to 0.0001 always including the dilution 0.001 as control. The graph of the transmission values of the second stock solution had an $R^2 = 0.9995$ (not shown), one week later even $R^2 = 0.9998$ (not shown). These graphs could be compared to the graph of the initial results of the Indian project (not shown) where an R^2 of 0.9996 was obtained. This shows the reproducibility of the results. With the dilution range of 0.01 to 0.0001 the transmission values from appr. 1 % to appr. 93 % were measured. Thus, the whole measuring range was covered.

4.2 Microscoping to analyse the structure of condensed milk and water sample colloids

To clarify the shape and size of the particles and the structure of condensed milk and water samples, the topic of colloids was examined. Microscoping (fig. 3.2a + 3.2b) revealed a similar structure of both, micelles within the milk and colloidal particles within the water samples. This confirms again the suitability of condensed milk as standard for turbidity determinations. There was no better microscope available at school, thus, no higher resolution of the structures could be achived.

4.3 Rejection of a linear correlation

Although the exponential correlation led to convincing results, a linear correlation was analysed in the dilution range from 0.00125 (appr. 60 % transmission) to 0.0001 (appr. 93 % transmission).

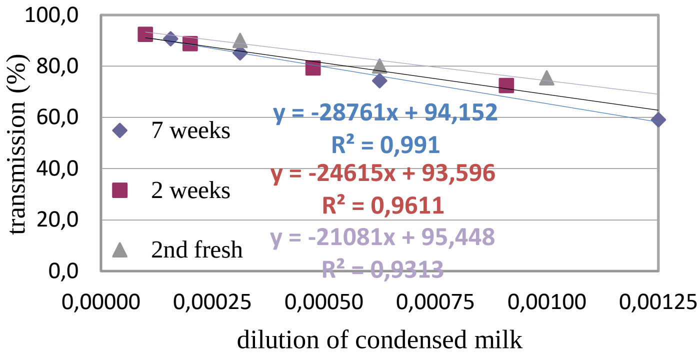


Figure 4.1: transmission of different condensed milk samples [in %] in correlation to their dilution. Established with dilutions beyond 1:800 (=0.00125). The linear correlation provides a maximum $R^2 = 0.991$.

In this range the correlation between the condensed milk concentration and the corresponding transmission appeared linear (fig. 4.1). But the R^2 ranged between 0.9313 to 0.991 and therefore was lower than the R^2 of an exponential correlation. Moreover, the linear correlation only allowed the measurement in a very high dilution range. In school projects, a larger range of measuring values had to be expected when testing environmental water samples.

4.4 Rejection of the extinction and the law of Lambert-Beer

Usually, photometric analyses are described by the law of Lambert-Beer [10] calculating the extinction. Thus, the applicability of this Lambert-Beer-correlation was checked although this law is related to homogenous solutions [10] whereas turbid water samples represent inhomogenous colloid solutions [14]. A linear correlation between the condensed milk dilution and the extinction could be found (fig. 4.2) but the resulting function could not be applied on the water samples reasonably as standard deviations were unacceptably high (fig. 4.3). As a possible explanation, the irregularity of size and shape of the turbidity causing particles was mentioned.

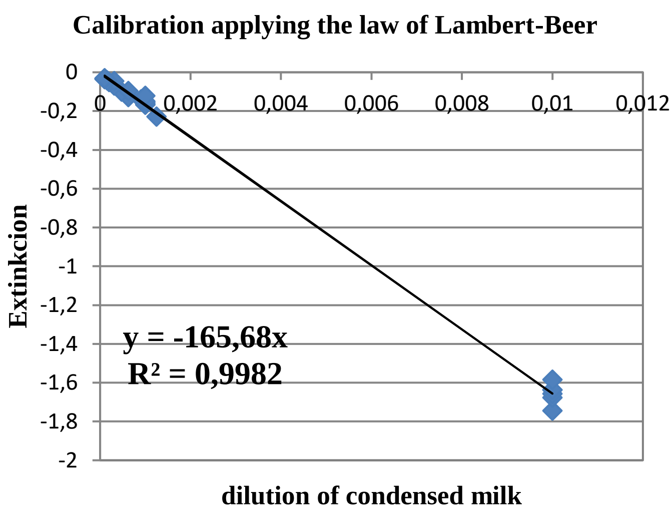


Figure 4.2: Linear correlation of the condensed milk dilution and the extinction according to the law of Lambert-Beer.

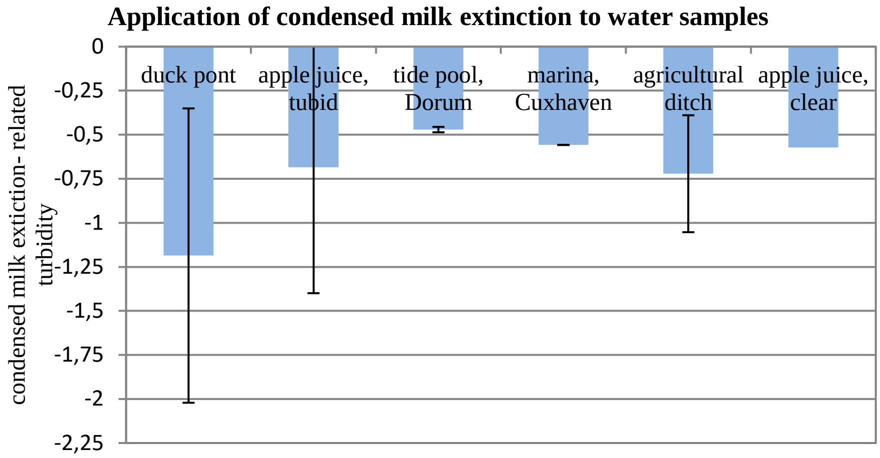


Figure 4.3: Extinction of each water sample calculated with the condensed milk turbidity. Very big standard deviations showing a non-suitable application on water samples, average ± standard deviation, n=1-4

Together, the evaluation with an exponential calibration graph yields most reliable results with the usage of a stock solution with a 0.01 dilution.

4.5 Improvement of the exponential calibration graph

With the help of the not shown graphs mentioned in 4.1, you can conclude that measuring the dilutions 0.01; 0.001 and 0.0001 is enough for generating a highly reliable calibration graph. This issue was proofed with further three point calibration graphs (fig 4.4).

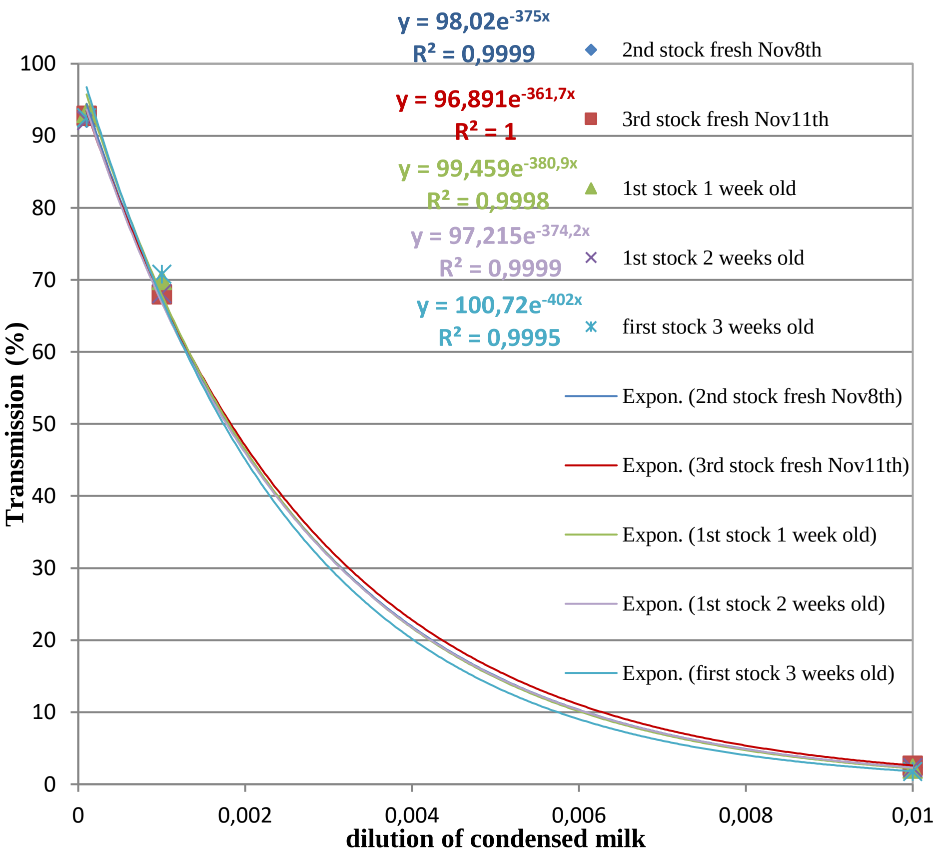


Figure 4.4: Three-point-graphs of different condensed milk dilutions with their correlated transmission [in %]. Established with stock solutions with different time periods of storage. All graphs provide a similar mathematical correlation with an R^2 from 0.9995 to 1.

From this analysis, reproducible results of the calibration graphs with R²s from 0.9995 to 1 were figured out. This confirmed the very high level of reliability.

It is inconvenient to generate a new calibration graph on each day of measuring. This was the reason to figure out whether the single generation of a general calibration obtained from many measuring repetitions could be used for later measurements of water samples or whether each day 3-point calibration graphs yield more reliable turbidity values. That general calibration graph showed a slightly lower R^2 than the three-point-graphs but still with a very high reliability (0.9961) (fig. 4.5). For comparison of the general calibration graph and the daily new one, two different samples were taken: A water sample from a private duck-pond and a sample from a naturally cloudy apple juice.

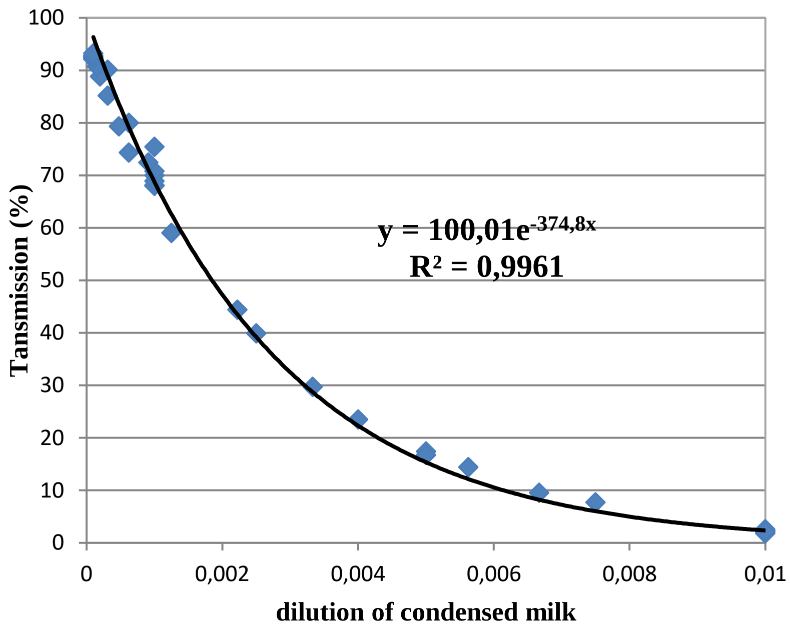


Figure 4.5: Transmission of all measured condensed milk dilutions [in %] in correlation to their dilution providing a reliable function with an R^2 = 0.9961 and yielding to a generally applicable calibration graph.

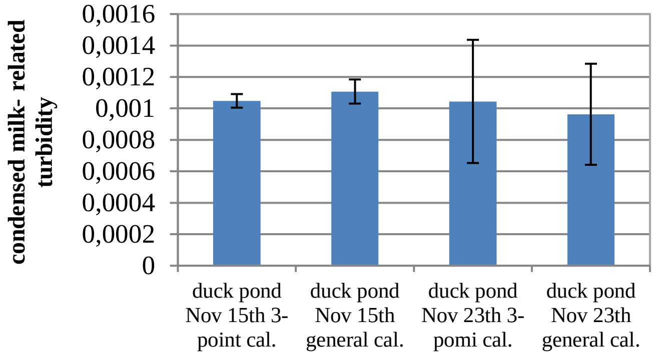


Figure 4.6: Condensed milk-related turbidity values of the duck pond determined at two different days. Both were measured with the daily measuring standard and the common measuring standard (established with fig. 4.5), average ± standard deviation, n = 3.

The transmission of these samples was measured on two different days with the dilutions 1:1; 1:2 and 1:4. The corresponding condensed milk turbidity values were calculated applying both types of calibration graphs. Figure 4.6 shows that means were always found within the variation range. Thus, both calibration graphs led to equivalent results. To measure different water samples with the same photometer, it is thus sufficient to once generate a general calibration graph with many measured values from an extended dilution range. This calibration graph and function can be used consistently with the same measuring device and the same setting (825 nm, function for our photometer see chapter 3.1). Not shown measurements with the naturally cloudy apple juice verify this result. The transmission of the duck-pond corresponded to a 1:1000 and the apple juice to a 1:200 dilution of the condensed milk. The relatively high standard deviation of the measurement from Nov. 23th might be caused by the storage of the sample in the refrigerator for one week. During this time, bacterial degradation processes might occur leading to increased mould formation.

4.6 Application of the condensed milk-related function to water samples

Because of the mould formation in the duck-pond water sample and the differences within the measurements of the same sample, the question arose, whether the turbidity of water samples with a high content of particulate matter can be determined with this method. Other water samples from the tide pool in the Wadden Sea in Dorum-Neufeld (high content of particulate matter), from the marina in Cuxhaven (low content of particulate matter) and from an agricultural ditch in Dorum (high content of particulate matter) were analysed and compared to the water sample from the duck-pond and the cloudy apple juice. Within all water samples, the average value of two to four measurements of the transmission was in an acceptable range of the standard deviation (fig 4.7). The transmission of the Wadden Sea corresponds to a 0.000728625 condensed milk dilution. It can be concluded that it is possible to calculate a realistic turbidity also for water samples with a high content of particulate matter. In this case multiple replications are meaningful, moreover, a dilution of the water sample in case of a low transmission (like the cloudy apple juice with 14 % of transmission) is helpful as well. It was shown that different dilutions of water samples can be used for calculating reliable turbidity values in contrast to other methods, where dilutions did not display proportional turbidity values [11]. The water sample of the marina in Cuxhaven with a transmission of >92 % corresponds to a condensed milk dilution of 1:10,000 and was almost clear. In this area the method is vague because of the exponential correlation. Additionally, clear apple juice of the same brand as the cloudy one was analysed. As the transmission was very high, it corresponds to a condensed milk dilution of 1:9500. It could be concluded that the yellowish colour didn´t falsify the value probably because of the maximum absorption of yellow at about 590 nm in contrast to the used wavelength of 825 nm [15]. This result is important as similar natural water samples might have a related colour because of humic substances found within water bodies [11]. Thus, yellowish-brownish coloured samples, e.g. the water of the Ganges, can be analysed with this method as well.

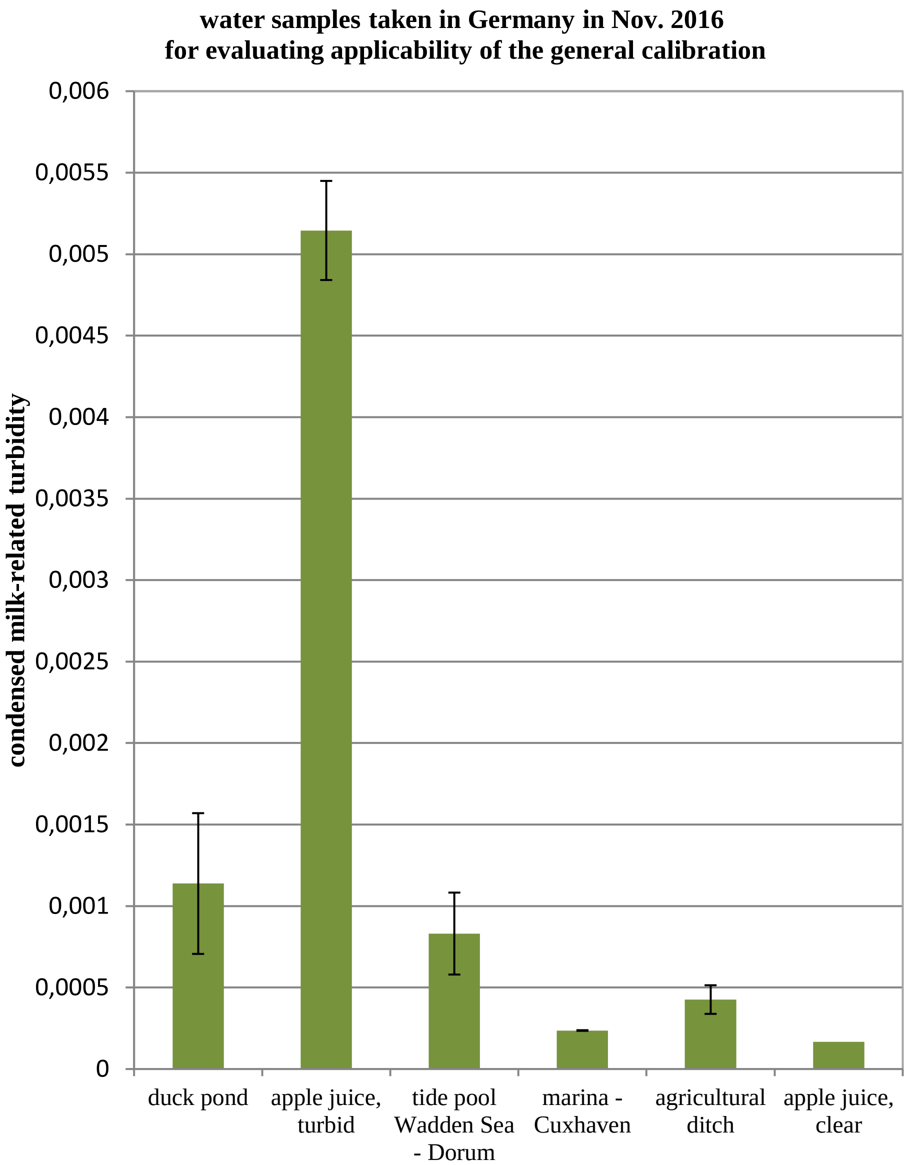


Figure 4.7: condensed milk-related turbidity values of water samples calculated with the condensed milk standard (established with fig. 4.5), average ± standard deviation, n 0 1-4.

4.7 Comparison of water samples from Germany and India by application of the developed method

Finally, the developed method for turbidimetry was applied to the water samples taken upon the German-Indian project. In the diagram of the water samples taken during the German-Indian project on May 2016 water samples from Germany are showed in green, those from India in blue. The average value and the standard deviation were determined. For example, the tide pool sample from the Wadden Sea had the highest turbidity and thus, much higher than the one of the river Ganges (fig. 4.8). The marina in Cuxhaven had the lowest turbidity. Interestingly, the tap water at the Indian school displayed a higher turbidity compared to the river Elbe.

The turbidity values of the water samples from the same German waters taken in May and in November 2016 were compared (fig. 4.9). The turbidity average values differed strongly from each other although they originated from the same water source but the seasonal natural influences can change the turbidity of the water extremely.

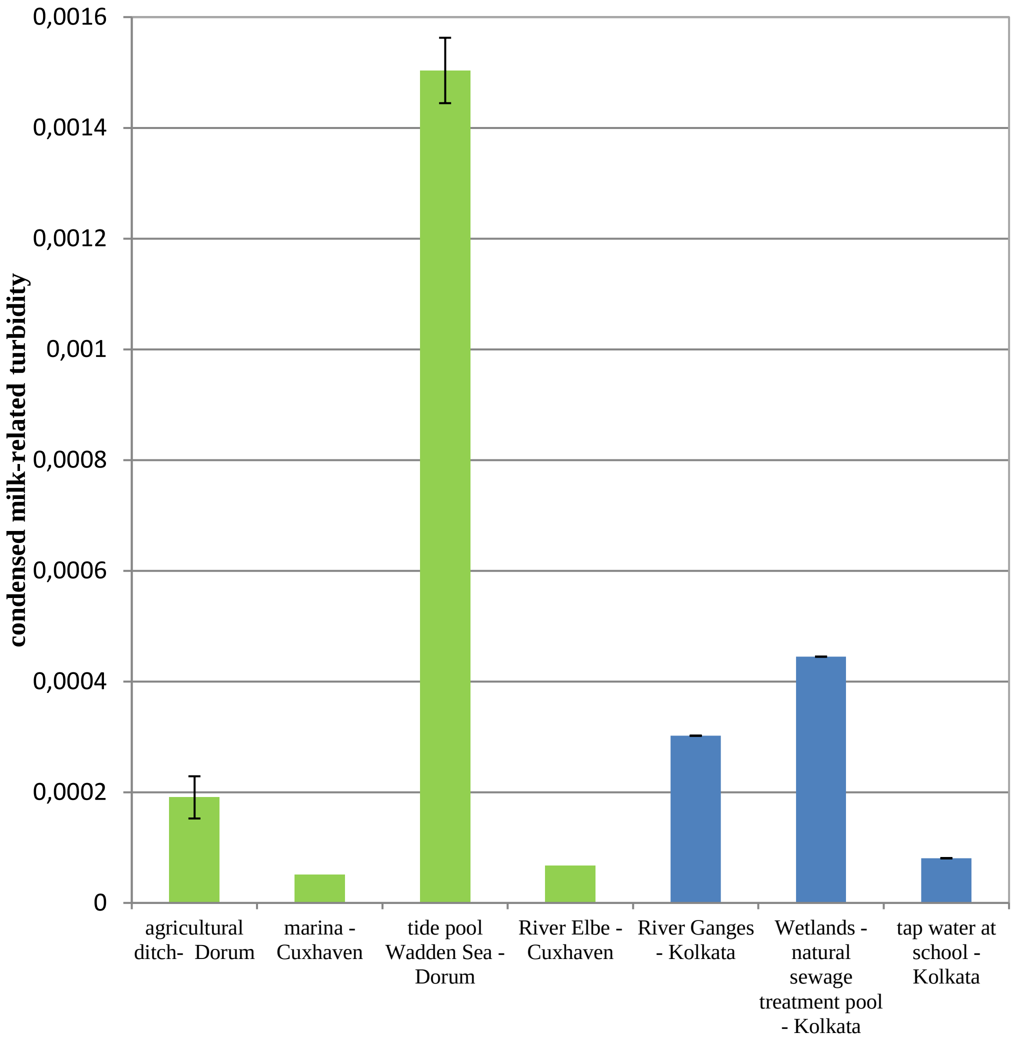


Figure 4.8: Water samples taken in May 2016 from Germany (green) and India (blue) calculated with the general calibration graph for condensed milk-related turbidity.

All of the three samples (fig. 4.9), having particulate matter or not, could be “diluted” by rain and so the transmission could rise. Additionally, the water sample from tide pool is influenced by low and high tide – whether the water rises or falls at the moment of sampling. Thus, turbidities always represent snap-shots. Nevertheless, it can be concluded whether the water body displays a generally high (such as the Wadden Sea) or generally low turbidity (such as the marina) (fig. 4.9). Among the analysis of further parameters of the water samples in May 2016, the amount of lead and arsenic were determined. Comparing the results to the respective condensed milk-related turbidity, no correlation between these parameters could be found (fig. 4.10).

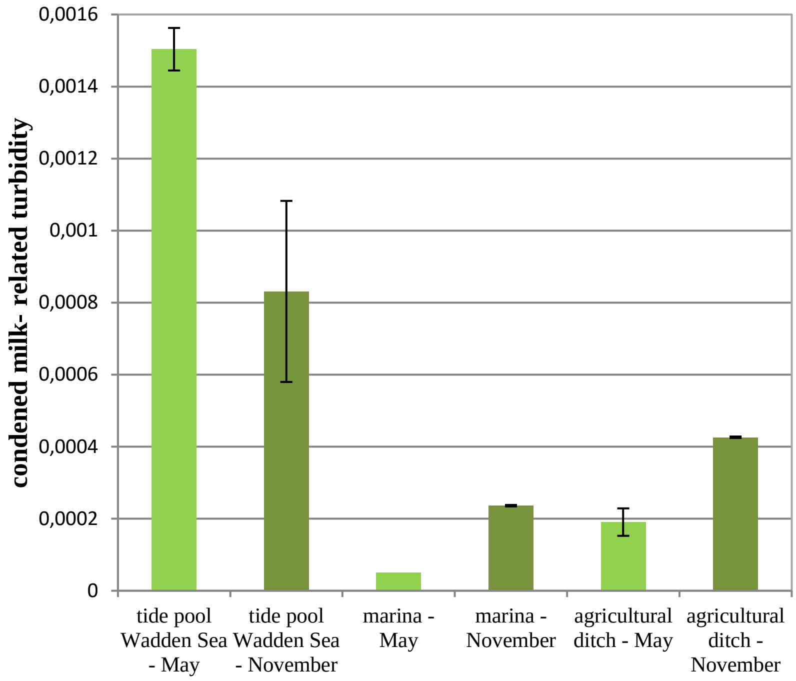


Figure 4.9: Comparison of the condensed milk-related turbidity values calculated from the water samples taken in May (light green) and November (dark green) 2016, average values ± standard deviation, n=1-3

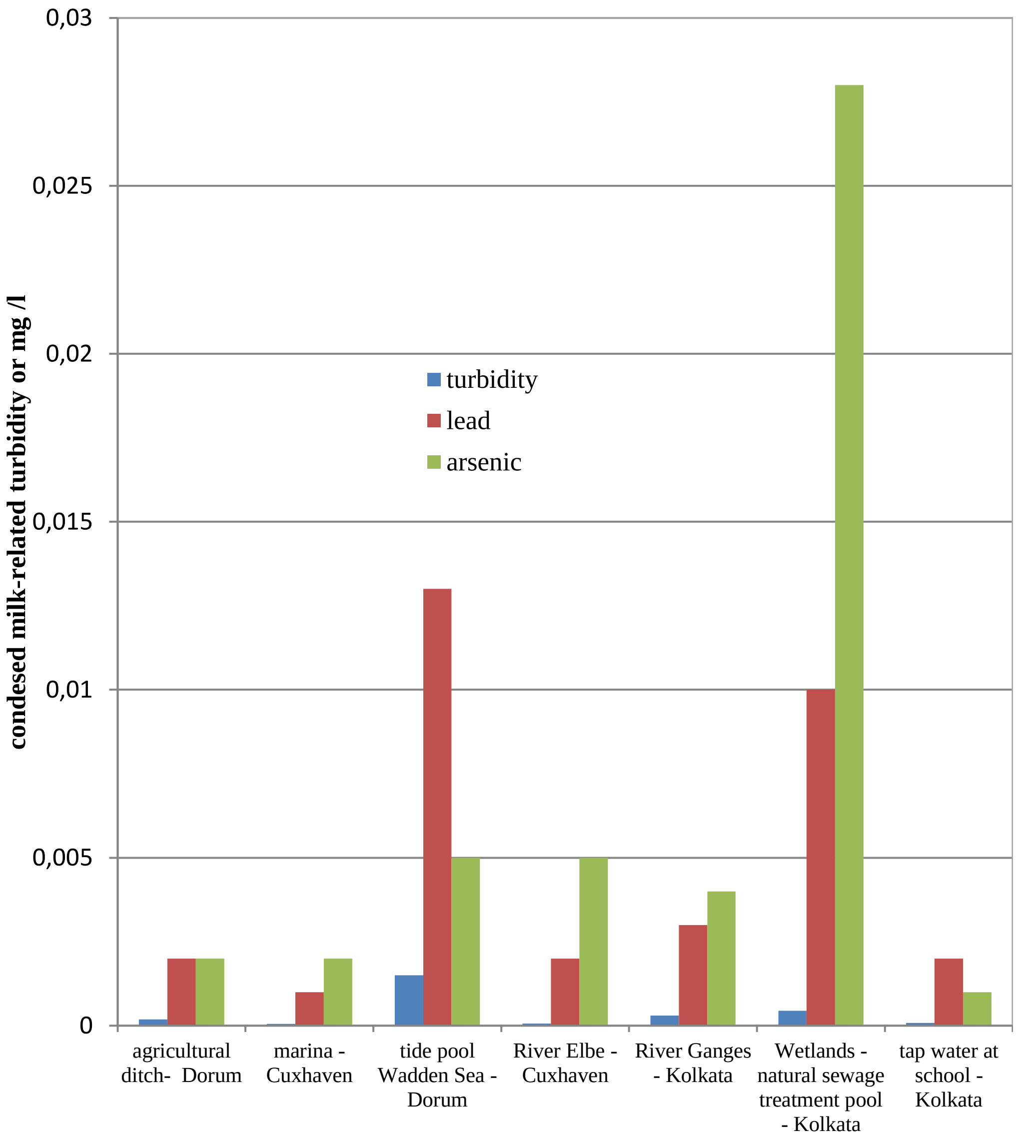


Figure 4.10: Condensed milk-related turbidity, amount of lead and arsenic are shown of each water sample, no correlation can be determined

Another observed parameter was the amount of iron in the water samples. The amount was measured within the samples from the river Ganges in Kolkata, the river Elbe in Cuxhaven, a tide pool of the Wadden Sea in Dorum-Neufeld and from the marina in Cuxhaven. Showing a linear correlation of both parameters, the determined function has a very high R^2 of 0.9971 (fig. 4.11). With this function ($y = 3418{,}9x - 0.152$) the amount of iron (y) could be calculated when inserting the turbidity (x) into the function. Of course, resulting values can be seen only as prediction in contrast to the directly measured values (fig. 4.12).

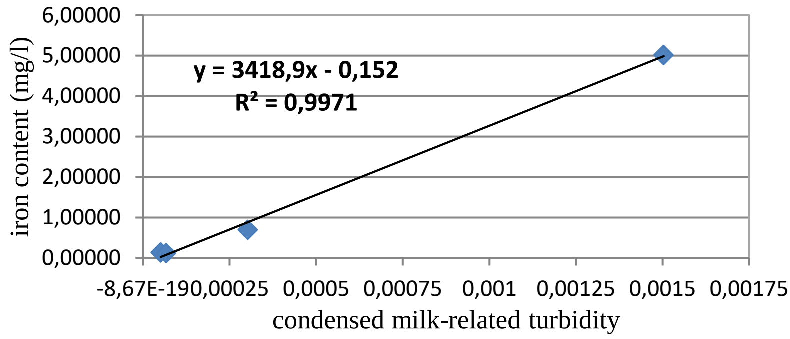


Figure 4.11: Iron correlated to the condensed milk-related turbidity calculated from the water samples taken in May 2016, n=4

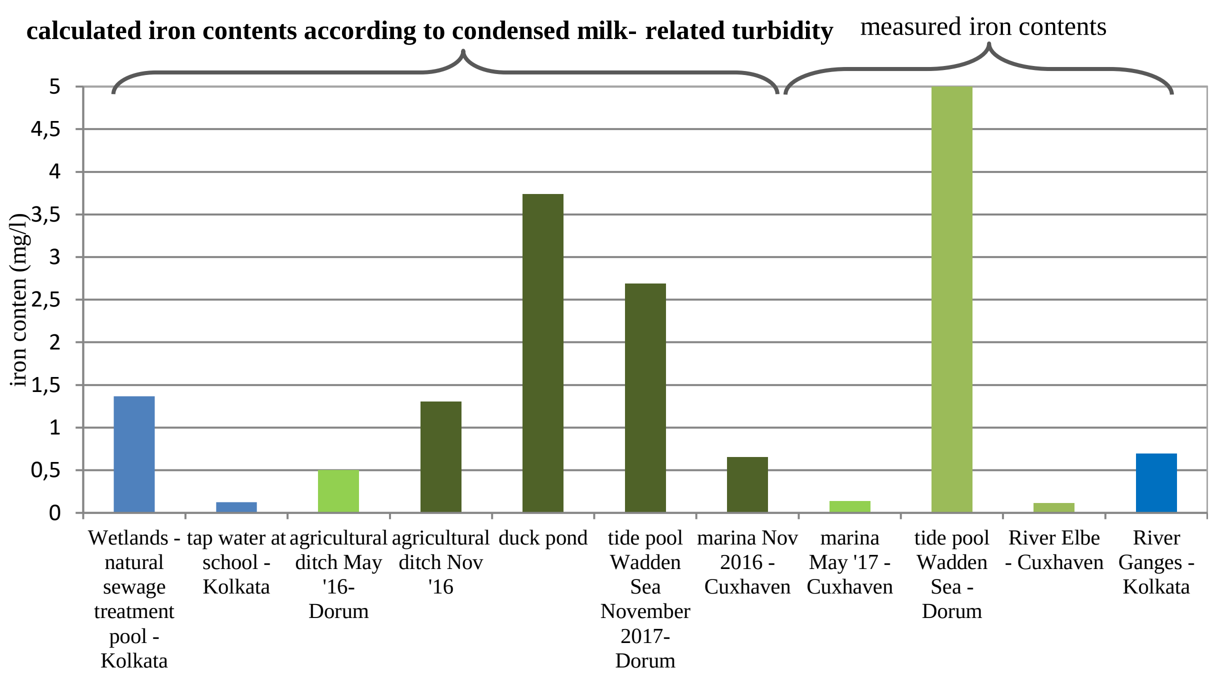


Figure 4.12: Iron content of four water samples on the right measured during the German-Indian project, on the left the iron content is calculated by the condensed milk-related turbidity correlation graph for the iron content (fig. 4.11).

Nevertheless when a sample had a low transmission, the amount of particles and colloids within this sample was high and this fact was causing a high amount of iron in case of a low transmission. The other way around was analogue: high transmission was caused by a low amount of particles and colloids, so, the amount of iron was low, too. Generally, iron can be found in water samples as an ion in colloids [12]. Thus, using the correlation to predict iron contents in turbid water samples makes sense. The tide pool showed a high amount of iron (5 mg/l), the marina and the river Elbe showed a low content which is quite similar to the predicted amount in the tap water at school in Calcutta (fig. 4.12). In tap water's low iron contents, e.g. may result from ferrous tubes.

4.8 Comparison of the condensed milk method and the formazine method

When doing water sample analysis like for the Ganges, it is interesting to compare your own results with literature values of other rivers [8]. However, when comparing these literature values with the condensed milk turbidity value, the numbers are in another range although the turbidity stays the same. Also, the formazine turbidity values are not comparable with any other standard because they are determined in the unit NTU and were generated with a dispersion measurement based on a formazine standard [8]. However, for the application of the condensed milk method at school, comparisons of the students' own samples are more important than comparison to literature values.

4.9 Significance of the developed method for school applications

A prospect of the presented project is the use of the condensed milk method in school during our next Indian exchange project to analyse the samples again and to find out whether the water quality of the Ganges will have improved by then.

During our trip to India, we analysed the water quality and even took a boat trip on the river. Recently, the Prime Minister of India, Narendra Modi, has announced to improve the situation in his country. Bangalore shall become an economic power, Delhi is going to get new toilets, muslim butcher won´t be allowed to slaughter cattle any longer, India shall become a digital country and even the water quality of the river Ganges will be improved. Until 2019, the water of the river Ganges shall be clean, but at this moment the river is one of the dirtiest waters in the world because many factories release 500 million litres of waste water a day into the river [13]. Additionally, the population is responsible for polluting the river with rubbish, moreover, dead cows are to be found in the river. Many governments have tried to start projects for cleaning the river – unsuccessfully. These plans show the necessity of analysing the resource water and the aspect of improving the water quality of the river Ganges is really interesting for the following exchanges between our school and our partner schools in Calcutta. The analysis on the water of the river will be continued for several future years to check whether the quality of the river will really improve. Thus, the turbidimetry is an important parameter while determining the water quality.

A statement about the water quality can be drawn by this method and supplied by further analysis, for example the amount of organic and anorganic substances that might be found by filtering and determining the ash-free dry weight. These substances can influence the flora and fauna of the water bodies concerning the photosynthesis of plants or the health of fish [11]. The latter can be influenced by reproducibility or growth or even develop increased cough [11]. Moreover, colloids may adsorb toxic components or heavy metals like lead or arsenic although no mathematical correlation was found in this study. The dissolved iron content of the water also indicates the availability of phosphate, i.e. a limiting factor for photosynthesis [16]. Reduced photosynthesis because of turbidity-caused lowered light intensities will result in a reduced bio production and, thus, less food for consumers such as fish [12]. These interrelations underline the importance of turbidity determinations for evaluating water qualities being a central factor of all those parameters.

5 Conclusions & Perspectives

The goal of the project was to develop this new method for turbidimetry. It worked out well, provided reliable results and showed that condensed milk can be used easily as a measuring standard for turbidimetry of natural water samples. There is an exponential correlation between the measured transmission and the level of dilution. With only three dilutions of 0.001; 0.0001 and 0.00001 it is possible to achieve an adequate and reliable calibration graph. You can get an increasingly reliable calibration graph by merging all measuring values of a measuring series in one graph, always including these 0.001; 0.0001; and 0.00001 dilutions. The condensed milk stock solution for developing a calibration graph can be stored in the refrigerator for up to seven weeks. After this period of time a new stock solution has to be set up. Storing it in the freezer is not possible due to coagulation. Dilutions in the range of 0.01 to 0.00001 have to be set up to cover the maximum range of transmission (93.3% till 0.8%). Once you have determined a measuring graph for the same turbidimetry device or photometer it is possible to use the resulting function for further transmission analyses. The method provided reliable values although the wavelength was at 825 nm and, thus, below the commonly used 860 nm or 880 nm. Samples showing yellowish-brownish color or high contents of particular matter can be analyzed as well, as found by the clear apple juice and Wadden Sea samples. The comparison of the values obtained from condensed milk standard and formazine is not possible, however, the presented new method within a series of samples offers the comparison among the samples. Moreover, predictions can be made regarding the iron contents of the water samples as the iron content proved to be correlated to the condensed milk-related turbidity.

Therefore, the use of this method in school is entirely adequate since you could use an old photometer, too. It is easy to reproduce and without any dangerous compounds. This method is going to be used for monitoring the water quality of the river Ganges in comparison to the Elbe in our future upon a German-Indian student exchange projects.

Finally, the presented study may contribute to make young people aware of the importance of preserving our fundamental resources, i.e. water. They may then stand up for a sustainable water resource management that is globally needed nowadays.

6 References

- [1] Margret Böck, Hanno Wachernig, Paticle Metrix GmbH, Meerbusch, Germany: https://www.particle-metrix.de/fileadmin/_processed_/5/5/csm_T31_7a4c3cffbb.png
- [2] Karsten Zührke: www.trinkwasserspezi.de/physparamter.pdf
- [3] Wikipedia Online encyclopaedia: https://de.wikipedia.org/wiki/Tr%C3%BCbung#/media/File:Tr%C3%BCbungssichttafel.gif
- [4] Hachlange GmbH, Düsseldorf, Germany, 2014: http://msds.hach-lange.com/msds/action_q/download%3Bmsds/msds_document/de%252F246149%252Epdf/lkz/II/spkz/en/TOKEN/eA068D1PG0d671ITFWjvZvw0kGA/M/rTpg-g
- [5] Klaus Lipinski, Editor Wissens-Portal ITwissen.info: http://www.itwissen.info/bilder/reflexion-absorption-und-transmission-an-einem-medium.png
- [6] T. Palberg, J. Horbach, Uni Mainz, Germany: http://player.slideplayer.org/2/671815/# KONDMAT I SS2006,
- [7] M. Tausch , M. von Wachtendonk, Schulbuch Chemie 2000+, C.C. Buchner Verlag, Bamberg, Germany, 1. edition, 2010
- [8] Wikipedia Online encyclopaedia:: https://de.wikipedia.org/wiki/Tr%C3%BCbung
- [9] BAMO IER GmbH, Mannheim, Germany: http://www.bamo.de/cbx/_ftp/grundlagen_trbungsmessung.pdf
- [10] U. Hübschmann, E. Links, Einführung in das Chemische Rechnen, Verlag Handwerk und Technik, Hamburg, Germany, 8. edition, unknown year
- [11] S. Schmutz, Literaturstudie des Niederösterreichischen Landesfischereiverbandes: Einfluss erhöhter Schwebstoffkonzentration und Trübe auf Fische, 2003,
- [12] T. Hofmann: Die Welt der vernachlässigten Dimensionen Kolloide, Chem. Unserer Zeit, Vol. 38, 24-35, 2004
- [13] Katrin Kuntz: “Kein schöner Land”, Der Spiegel, Nr. 1, 76-81, 2.1.20162004,
- [14] Wikipedia Online encyclopaedia:: https://de.wikipedia.org/wiki/Extinktion_(Optik)
- [15] Wikipedia Online encyclopaedia:: https://de.wikipedia.org/wiki/Spektralfarbe
- [16] R. Remé, G. Sack, M.Schäfer, C. Steinert: Natura 11/12 Biologie für Gymnasien Niedersachsen G8, Ernst Klett Verlag, Stuttgart, Leipzig, Germany, 1. edition, 2010